Evidence for Different Formation Environments for Fe-Sulfides from Interplanetary Dust and From Meteorites

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Abstract No. Flyn2029
Beamline(s): **X26A**

Introduction: On average the chondritic interplanetary dust particles (IDPs), which are samples of asteroids and comets collected by NASA from the Earth's stratosphere, are enriched in the volatile elements by about a factor of 3 over the most volatile-rich meteorites (Flynn et al., 1996), called the carbonaceous chondrite meteorites. This suggests the IDPs and the meteorites formed in different environments. However individual IDPs weigh only a few nanograms and may sample different parent bodies, The small size necessitates measuring many particles to obtain a meaningful average, and even then that composition may reflect the average of several different formation environments.

Some single mineral grains, including olivine, pyroxene, and sulfides, are also found on the stratospheric collectors. These single mineral grains are likely to come from the same parent bodies as the chondritic IDPs. However, because these single mineral grains are more dense than the chondritic IDPs, they have higher settling rates in the stratosphere. Thus, we cannot derive the bulk composition of the IDP parent bodies by simply averaging the compositions of the chondritic IDPs with the single mineral grains in the proportions at which they occur on the collector surfaces. Thus, comparison of the average composition of the IDPs with the bulk composition of meteorites is not the best approach to determine if the two materials are different. Comparison of individual minerals in the two materials may provide a better test, but the olivines and the pyroxenes have low volatile contents, leaving only the sulfides, among the major minerals, for comparison of volatile elements.

Methods and Materials: Selenium and sulfur have very similar geochemical behavior, and in primitive chondritic meteorites Se is hosted almost exclusively in the sulfides – pyrrhotite, pentlandite, triolite, and cubanite (Dreibus et al., 1995). Thus, a comparison of the Se contents of IDP sulfides with that of meteorite sulfides should indicate if the sulfides in these two materials formed under the same conditions. Pyrrhotite is the most common Fe-sulfide in IDPs, spanning the size range from sub-micrometer grains within chondritic IDPs up to 20 to 35 micrometer individual pyrrhotites, sometimes with small amounts of chondritic material adhering to their surfaces, We used x-ray micro-diffraction, performed at X26A, to identify 5 pyrrhotite-dominated IDPs, each about 20 micrometers in size. We measured the chemical composition of each of these pyrrhotite-dominated IDPs using the X-Ray Microprobe at X26A. We had previously measured the Se contents of 20 pyrrhotite grains, each about 50 micrometers in size, hand-selected from the primitive chondritic meteorite Orgueil (Greshake et al. 1998).

Results: The Orgueil pyrrhotites averaged 65 ppm Se, with a range from 36 to 100 ppm (Greshake et al. 1998). The 5 pyrrhotite-dominated IDPs have Se contents of 90, 100, 110, 110, and 120 ppm, with four of the pyrrhotite-dominated IDPs having Se contents as high as or higher than the most Se-rich Orgueil pyrrhotite. The mean Se content of the pyrrhotite-dominated IDPs (~110 ppm) is 1.7 times that of the Orgueil pyrrhotites. We cannot exclude thermal modification of the pyrrhotite IDPs during atmospheric deceleration. In fact, the x-ray diffraction patterns of each of the 5 pyrrhotite IDPs showed weak magnetite powder diffraction rings, indicating that some magnetite was formed during the atmospheric entry heating pulse. However, the pulse heating of Orgueil pyrrhotites lowered their Se content (Greshake et al. 1998). Thus, if the pyrrhotite IDPs experienced thermal modification, the pre-atmospheric Se content would have been higher than the amount we measured.

Conclusions: IDPs differ from meteorites not only in bulk composition, but in the element ratios in an individual mineral – pyrrhotite. These results indicate that the pyrrhotite-dominated IDPs formed in a region with a higher Se/S ratio than the pyrrhotite in the primitive meteorite Orgueil, or that the IDP pyrrhotite formed at a different temperature than the Orgueil pyrrhotite. In either case, IDP pyrrhotites sample a different formation environment than the chondritic meteorites, consistent with our prior inferences that chondritic IDPs formed in a different environment than the chondritic meteorites based on the volatile enrichment of IDPs (Flynn et al., 1996).

Figure 1. L2021D8, a pyrrhotite IDP measuring ~20 micrometers in its longest dimension.

Acknowledgments: The pyrrhotite-dominated IDPs were collected by NASA and provided to us by the extraterrestrial materials curatorial facility at the NASA Johnson Space Center. This work was supported by NASA Cosmochemistry Grant NAG-5-9393.

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